TACKLING CLIMATE CHANGE

THE ENERGY PERFORMANCE OF NEW RESIDENTIAL BUILDINGS IN ENGLAND

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ABSTRACT

Purpose: Using the new build residential sector in England as its basis, this study examines how climate change is being tackled, and analyses the practicality of implementing the current carbon dioxide and energy requirements proposed by UK legislation, sustainability codes, and local authority planning requirements.

Design/methodology: The paper outlines the current climate change facts, analyses the global, national, regional and local requirements for energy strategy and highlights the differences that have been found. The impact of different design strategies on achieving the various requirements is then modelled, using case study data.

Findings: The preliminary findings of this study show that there are many conflicts in the interpretation on the requirements at different levels and that the methods being used in the residential sector in England to tackle climate change are fraught with problems. They also show that the current additional cost of a sustainable building is prohibitively high. In order to successfully implement environmentally sustainable solutions, there is a need for clearer regulations, guidelines and definitions, and for significant incentives.

Practical implications and value of paper: The study highlights the difficulties of implementing the energy and carbon dioxide commitments using the UK as its basis and makes a number of recommendations to make the implementation successful and to overcome the existing barriers.

KEYWORDS

Climate change, sustainable construction, energy, carbon dioxide emission requirements, implementation

CLIMATE CHANGE

"There is still time to avoid the worst impacts of climate change, if we act now and act internationally"[1].

There is now very strong evidence[2] that since the late 1800s the earth's average surface temperature has risen by 0.74°C. Since this period, there has been an ever increasing consumption of fossil fuels as oil, gas and coal, significant deforestation, and the practice of farming methods[3] that has resulted in emissions of six principal greenhouse gases[4]: Carbon Dioxide (CO_2), Methane (MH_4), Nitrous Oxides (N_2O), Hydrofluorocarbon (HFC), Perfluorocarbon (PFC) and Sulphur Hexafluoride (SF6).

These gases occur naturally and they are critical for life on earth as they keep some of the sun's warmth from reflecting back into space. Without them the world would be a cold and barren place. Nevertheless in increasing quantities, greenhouse gases are pushing the global temperature to artificially high levels and altering the climate.

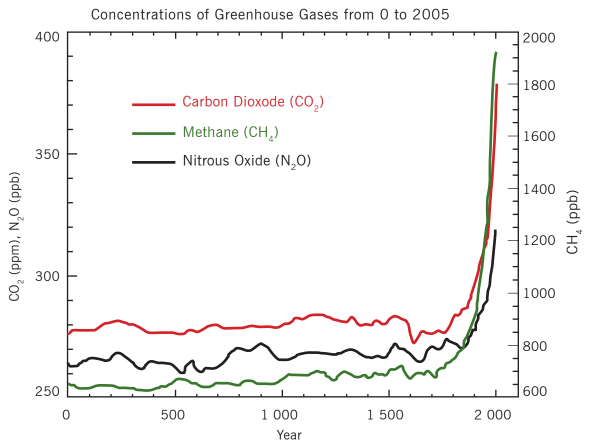

Figure 1: *Concentrations of greenhouse gases from 0 to 2005[2].*

One reason for the current concern about climate change is the rise in atmospheric carbon dioxide concentrations indicated in parts per million (ppm), shown in Figure 1. During the last 650,000 years carbon dioxide concentrations have varied between 180ppm and 300ppm. In 2007, the concentrations of atmospheric carbon dioxide were 379ppm[2].

Another concern relates to the speed of the recent warming: 0.55°C since 1940. During the ice age and warm interglacial periods the mean temperature changed between 4°C and 7°C; however, the process took about 5,000 years.

It fell to scientists to draw international attention to the threats posed by global warming. In 1997, linked to the United Nations Framework Convention on Climate Change (UNFCCC), the Kyoto Protocol was adopted in Japan and entered into force in 2005. The Kyoto Protocol is an international agreement that sets binding targets for 37 industrialised countries and the European community (EC 15) for reducing the six principal greenhouse gas emissions over the five-year period 2008-2012[3] by an average of 5% against 1990 levels.

In the year 2000 the world's greenhouse gas emissions were about 3[4] Gt of carbon dioxide equivalent per year[5]. Of these total greenhouse gas emissions the carbon dioxide emissions from the energy sector contributed 74% the largest proportion (Figure 2).

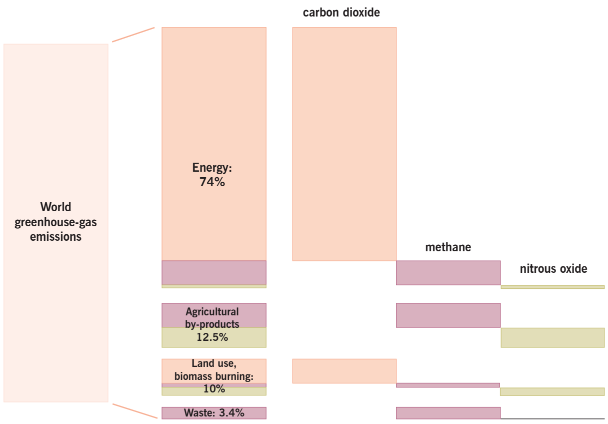

Figure 2: *Break down of the world's greenhouse gas emissions in 2000 by cause and by gas[2].*

In 2006 the UK emitted a total of 652Mt carbon dioxide equivalent of greenhouse gas emissions[6], 85% of which have been carbon dioxide emissions[7]. Data shows[6] that the building sector accounts for 63% of this, and the residential sector is responsible for about 27% of these total carbon dioxide emissions in 2006. 73% of the residential carbon dioxide emissions resulted from space and water heating[8].

INTERNATIONAL, NATIONAL, REGIONAL AND LOCAL ENERGY STRATEGY REQUIREMENTS

Different levels of hierarchy including international, national, regional and local intergovernmental/governmental institutions define energy strategies and set out targets for tackling climate change.

The UNFCCC is the overall framework for intergovernmental efforts to tackle the challenge posed by climate change. One of the earliest obligations of the UNFCCC parties is the Kyoto Protocol. The EU Member States committed to collectively reduce their greenhouse gas emissions by 8% below 1990 levels within the first five year commitment period.

Reducing energy consumption is among the main goals of the European Union. 40% of the energy is consumed by the 160 million buildings[9]. In order to implement the EU targets and commitments and to lead to substantial increases in investment in energy efficiency measures within these buildings, the Energy Performance of Buildings Directive[10] (EPBD) came into force in 2003. The EPBD aims to ensure that new buildings meet the set requirements, make Energy Certificates available when buildings are constructed, sold and rented and to inform the users of buildings about methods and practices to enhance energy performance.

In response to this directive, the UK Government set targets to cut the national carbon dioxide emissions by 80% below 1990 levels by 2050[11]. By 2020, 20% of the European Energy Consumption will be saved through improved energy efficiency and the renewable energy supplies will be increased by 20% by 2020[11]. To achieve these targets, the UK Government amended the Building Regulations (BR) Approved Document Part L[12] in 2006 and is consulting on the changes that will come into force in October this year (2010). Compliance with BR is mandatory. In addition, the UK Government introduced the discretionary Code for Sustainable Homes (CSH)[13]. The CSH is an environmental assessment method for rating and certifying the performance of new dwellings from level 1, enhanced sustainability, to level 6, zero carbon.

On a regional level the Greater London Authority published its Energy Strategy[14]. The strategy aims to improve London's environment, reduce the capital's contribution to climate change, tackle fuel poverty and promote economic development by using less energy, using renewable energy and supplying energy efficiently. On a local level, Richmond upon Thames is an exemplary Borough in the Greater London Area putting sustainability as a priority in its Core Local Development Strategy[15]. The Borough requires every new development to comply with its supplementary planning document, the Sustainable Construction Checklist [16]. The Checklist requires a CSH level 3 rating for all new residences and the predicted site carbon dioxide emissions have to be reduced by at least 20% through the use of renewable energy.

CASE STUDY AND FINDINGS

The dwelling chosen for this case study is a two storey, detached property of approximately 160m^2 and located in a suburban area in the South West of London. All calculations have been performed with the National Home Energy Rating Plan Assessor Version 4.2.28[17]. It is assumed that the dwelling is naturally cooled, the primary heating systems tested include gas boiler, warm air, warm air with heat recovery, biomass boiler, ground source and air source heat pumps and a communal combined heat and power system. Appropriate systems for an urban context, such as photovoltaic elements, solar hot water elements, biomass boiler, ground source and air source heat pumps have been tested to comply with the local planning requirement to offset at least 20% of the predicted carbon dioxide emissions by renewable energy technologies.

Two different construction standards have been analysed:

1. Standard construction: the dwelling complies with BR Part L1A
2. Improved construction: the dwelling exceeds BR Part L1A requirements

Table 1: *Assumptions made for the construction elements of type one and two.*

Building Element	Type 1, standard construction	Type 2, improved construction
Floor, wall, roof	0.25W/m^{2}K	0.12W/m^{2}K
Windows	2.0W/m^{2}K	0.8W/m^{2}K
Doors	2.0W/m^{2}K	1.0W/m^{2}K
Air tightness level	9m^3/m^{2}hr@50Pa	5m^3/m^{2}hr@50Pa

ENERGY PERFORMANCE CALCULATIONS

In England, the energy performance of a building is expressed in carbon dioxide emissions, determined as Dwelling Emission Rate (DER in $kgCO_2/m^2yr$). The DER arising from the predicted energy demand of a dwelling has to be calculated to prove compliance with Building Regulations and in order to produce Energy Performance Certificates.

To comply with Building Regulations, the actual carbon dioxide emissions of the dwelling are compared with those of a notional dwelling. The emissions of the actual dwelling have to be equal to, or lower than the targeted emission rate of the notional dwelling. The energy data for the Energy Performance Certificate is also based on the carbon dioxide emissions, the DER respectively.

However, for both verifications the emissions arising through cooking and electrical appliances are disregarded. In addition, the assumptions made for the use of a secondary heating system and for the use of energy efficient lighting are different, although the same terminology, the DER, is applied.

Therefore, the carbon dioxide emission predictions for the same dwelling vary, depending on the evidence's definition, and are not realistic. Realistic emissions that reflect the energy demand for cooking and electrical appliances, determined by the National Home Energy Rating (NHER), are approximately 50% higher (Figure 3).

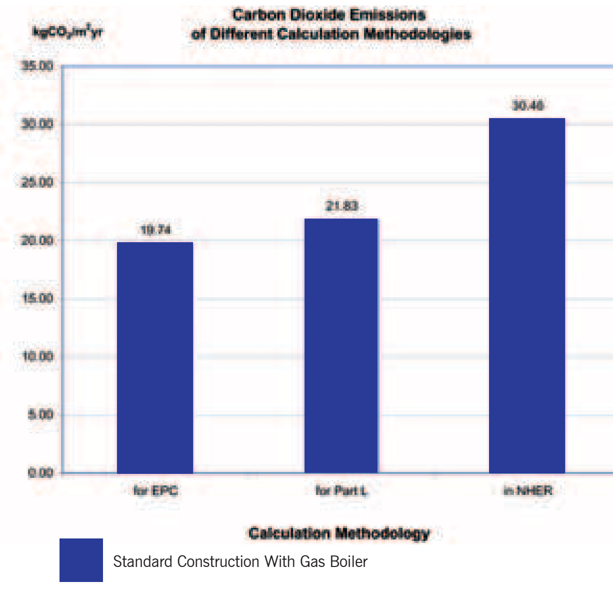

Figure 3: *Predicted carbon dioxide emissions for the standard construction as defined for Energy Performance Certificates (EPC), Building Regulations (Part L) and by National Home Energy Rating (NHER).*

THE ENERGY AND CARBON DIOXIDE TARGETS

The decisive factor in England to conserve fuel and power is the carbon dioxide emissions. However, the best heating option in terms of carbon dioxide emissions is not the best heating option in terms of energy demand.

The biomass boiler has the lowest carbon dioxide emissions, because the fuel, wood pellets or chips, is a carbon dioxide capture storage and has low carbon dioxide emissions in its production process. But the energy demand of the biomass boiler is the highest of all options tested, because of the low overall efficiency of the system.

Conversely, providing heat pumps as heating systems result in the best performance in terms of energy demand, because of the very high overall efficiencies of the systems. However, these systems run on electricity, which is very carbon dioxide intensive in its generation, and therefore achieve only an average value in terms of carbon dioxide emissions (Figures 4 and 5).

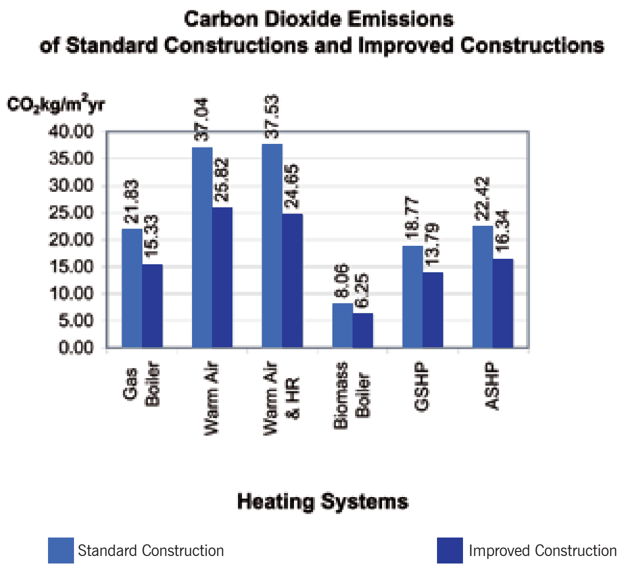

Figure 4: *Carbon dioxide emissions for different heating strategies for the standard and the improved construction.*

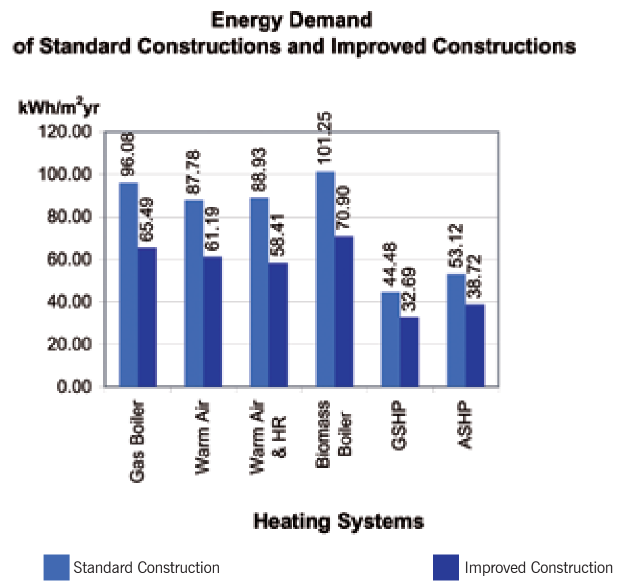

Figure 5: *Energy demand for different heating strategies for the standard and the improved construction.*

Therefore the definition of the carbon dioxide emissions as a decisive factor to conserve fuel and power is in conflict with the target to implement energy efficient heating solutions. Furthermore, these calculations do not reflect the fact that in the near future the proportion of electricity generated by renewable energy systems will increase and therefore heating systems running on electricity will have lower carbon dioxide emissions.

COGENERATION OF HEAT AND ELECTRICITY

Combined heat and power systems (CHP) generate electricity and heat, and achieve 30% higher efficiencies than systems that produce heat and electricity separately[18]. Therefore the carbon dioxide emissions of a CHP system are the lowest of the systems tested in the case study.

Gas CHP systems are defined as Low or Zero Carbon Technologies in the UK. However, they are not recognised as renewable energy systems and do not count toward the requirement to incorporate 20% renewable energy technologies as required on local policy level.

Hence, although gas CHP systems are significant energy saving measures, in practice they are not often incorporated, as the capital cost for the systems are higher than those of gas boilers and additional investment has to be made to comply with the renewable energy requirement.

RENEWABLE ENERGY TECHNOLOGIES

In the UK, on a local policy level, it is a requirement that the predicted carbon dioxide emissions are offset by at least 20% by on-site renewable energy technologies. The systems that are accepted as renewable energy technologies vary on different policy levels and a generic definition is hard to find. In order to demonstrate compliance, complex and confusing calculations are required.

In addition, the required amount of energy generated from additional renewable technologies, for example photovoltaic or solar hot water panels, increases with improved construction standards where the primary heating system is a renewable energy technology, for example a heat pump (Figure 6). This clearly does not promote good basic passive sustainable design.

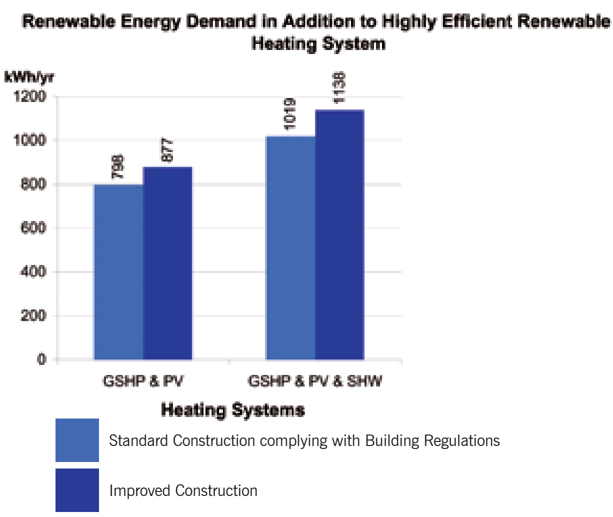

Figure 6: *Amount of electricity generated by additional renewable energy technologies (photovoltaic and solar hot water panels) incorporated to the standard construction and the improved construction in order to meet the 20% renewables requirement.*

FINANCIAL ASPECT

The cost for the additional sustainability requirements arise through improved construction standards and building services, the cost for the renewable energy technologies and the procedures for the Code for Sustainable Homes assessment and certification. From experience it can be seen that the additional cost of achieving, for example, CSH level 4 (out of 6) and to incorporate 20% renewable energy technologies to a typical dwelling ranges between US $15,000-25,000.

To overcome the financial barriers several schemes have been put into place by the UK Government. Until 2011 grants are available for the installation of Low or Zero Carbon Technologies. Stamp Duty Exemptions up to 4% are available for the first acquisition of zero-carbon homes. From April 2010, a Feed-In-Tariff is paid for every kWh of electricity generated by renewable energy systems and a Renewable-Heat-Incentive is currently to be launched by 2011.

However, the financial incentives are complex and refer to various terminologies, which is confusing. They also cover only a fraction of the additional cost of a sustainable new building.

CONCLUSIONS

To implement the international targets to tackle climate change, three strategies are pursued in the building sector of the UK: to be lean, to be clean and to be green. The implementation of these three strategies is regulated by the mandatory Building Regulations and the optional Code for Sustainable Homes on a national policy level and the mandatory supplementary sustainability planning documents on a regional and a local level.

However, the implementation of these strategies becomes unnecessarily confusing, complex and therefore time-consuming and expensive. To overcome these barriers and to successfully tackle climate change, a number of recommendations can be made:

1. Targets and strategies addressing the reduction of all the principle greenhouse gases.
2. Regulations that are valid on every policy level.
3. Calculation procedures for compliance with these regulations that are clearly defined, and consistent, including all energy consuming processes of a dwelling and an allowance for situations where there is no primary heating system.
4. To overcome the conflicts and difficulties between the targets to be lean, to be green and to be clean, the required evidences need to be based on the predicted primary energy demand of the dwelling in kWh/m^{2}yr, rather than on the CO_2 emissions in kg/m^{2}yr.
5. One terminology, a clear definition of "renewable energy technologies" and a simple calculation procedure to demonstrate compliance with the renewable energy requirements need to be agreed.
6. Transparent, easily accessible and lucrative financial incentives need to be offered to build environmentally sustainable buildings.